New LCA Theses

Cumulative Energy Demand and Cumulative Emissions of Photovoltaic Systems in the European Community

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The use of renewable energy systems meets the requirements of being environmentally compatible and resource conserving. However they also hold expenditures for materials and energies in regard to production and use and thus consequences regarding Cumulative Energy Demand (CED) and Cumulative CO_2-, NO_x, and SO_2-Emissions.

The investigation is focused on the question, whether the national differences of the electricity supply within the European Community have an affect upon the results of an ecological assessment of photovoltaic systems.

Considering the use of the photovoltaic systems in the different countries attention is paid not only to country-specific irradiation conditions, but also to different substitution of the primary energy, as well as the related avoidance of emissions.

The most common photovoltaic systems presently and in the near future are monocrystalline- (sc-), multicrystalline- (pc-) and amorphous-silicon (a-Si) based.

In order to give a 'round picture' in respect to differences within the European Union seven representative countries are chosen, which fulfill the following requirements:

- great importance for the production of solar cells and modules within the European Union,
- distinct use of photovoltaic systems within the European Union,
- high national overall efficiencies of electricity supply and
- low CO_2 emission factors.

This leads to the selection of Germany, France, Italy and Spain in reference to the production of the systems, whereas the view onto their use results in Germany, France, Italy, Netherlands and Spain. At last with regard to ecological criteria Austria is included with the highest efficiency of electricity supply and Sweden with lowest CO_2 emissions.

All three process chains of the photovoltaics production are considered to have equal production conditions within the examined countries. Essential data for the investigations are:

- process energy demand and direct process emissions from the production of the photovoltaic systems,
- material demand from the production of the photovoltaic systems,
- specific Cumulative Energy Demand and Cumulative CO_2-, NO_x and SO_2 emissions of the material supply,
- country-specific efficiencies of electricity supply and CO_2-, NO_x- and SO_2 emission factors per kWh electricity.

Data for the production processes of the solar systems are taken from various literature sources and process chains and material balances are compiled for:

- process chain of the production of monocrystalline, multi-crystalline and amorphous silicon solar modules,
- material balance of a solar inverter,
- material balance for the support structure of the solar modules and wiring of the photovoltaic systems.

The same peak power is presumed for comparison of the systems respectively and due to the different efficiencies and thus different areas required the multi-crystalline systems turn out to be best followed by the amorphous and the monocrystalline systems.

The investigated countries are divided into two groups. One group – consisting of Austria and Sweden – with lower CEDs than the other one, whereas the CEDs in the second group approximately lie within the same margin.

The Cumulative CO_2-Emissions show their lowest values not only in Austria and Sweden but also in France, while Cumulative NO_x- and SO_2-Emissions tend to result in lower values when production takes place in Sweden or France. Especially pc-Si-Systems are found to give best results, whereas sc-Si-Systems lie at the end of the line.

The use of the photovoltaic systems results in highest primary energy substitution in Spain and highest avoided emissions in Italy.

In conclusion a comparison between production and use of the systems as well as calculation of energy payback time and emission related payback time is done.

By comparison of systems produced and utilized within the same country, those in Spain come off best with the lowest energy payback time and those in Italy with the lowest emission related payback time. The determinant for this result is formed by the variation of the potential of substitution when using the systems in different countries. In comparison the influence of national Cumulative Energy Demands or Cumulative Emissions of production is of small importance.

Production and utilization of photovoltaic systems within the same country do not necessarily give ideal results. As Cumulative Energy Demands and Cumulative Emissions in some countries fail low on the production side – due to low overall efficiencies of electricity supply and low emission factors – the substituted primary energies and avoided emissions in those countries are too low to achieve the best payback times. These can still be reduced when production and utilization are looked at separately.

Subsequently the lowest energy payback time follows from production of systems in Austria and utilization in Spain.

Lowest emission related payback times always emerge when systems are used in Italy, whereas on the production side Sweden gives best CO_2- and SO_2-related payback times and production in France results in lowest NO_x-related payback times. However the effect of a dislocation of the production of photovoltaic systems would be affected, if other industries were displaced. For this reason a shift does only make sense when there is no displacement or when over-capacities on side of the electricity production do exist.

In the end in a sensitivity analysis it is shown that even with future improvements of the module efficiencies multicrystalline systems come off better than a-Si and sc-Si systems. Since the gap between the amortization times of the different systems will be reduced it is concluded that a-Si systems with even further progress might close in on pc-Si systems in the future.

As superordinate result one can determine that a view on the ecological compatibility of photovoltaic systems should not be limited alone to national criteria. In fact it is reasonable to combine pro and cons of production and use of photovoltaic systems within different countries to acquire optimal results.

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